RESEARCH DEPARTMENT

An active deflector suitable for u.h.f. television transmissions

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

AN ACTIVE DEFLECTOR SUITABLE FOR U.H.F. TELEVISION TRANSMISSIONS

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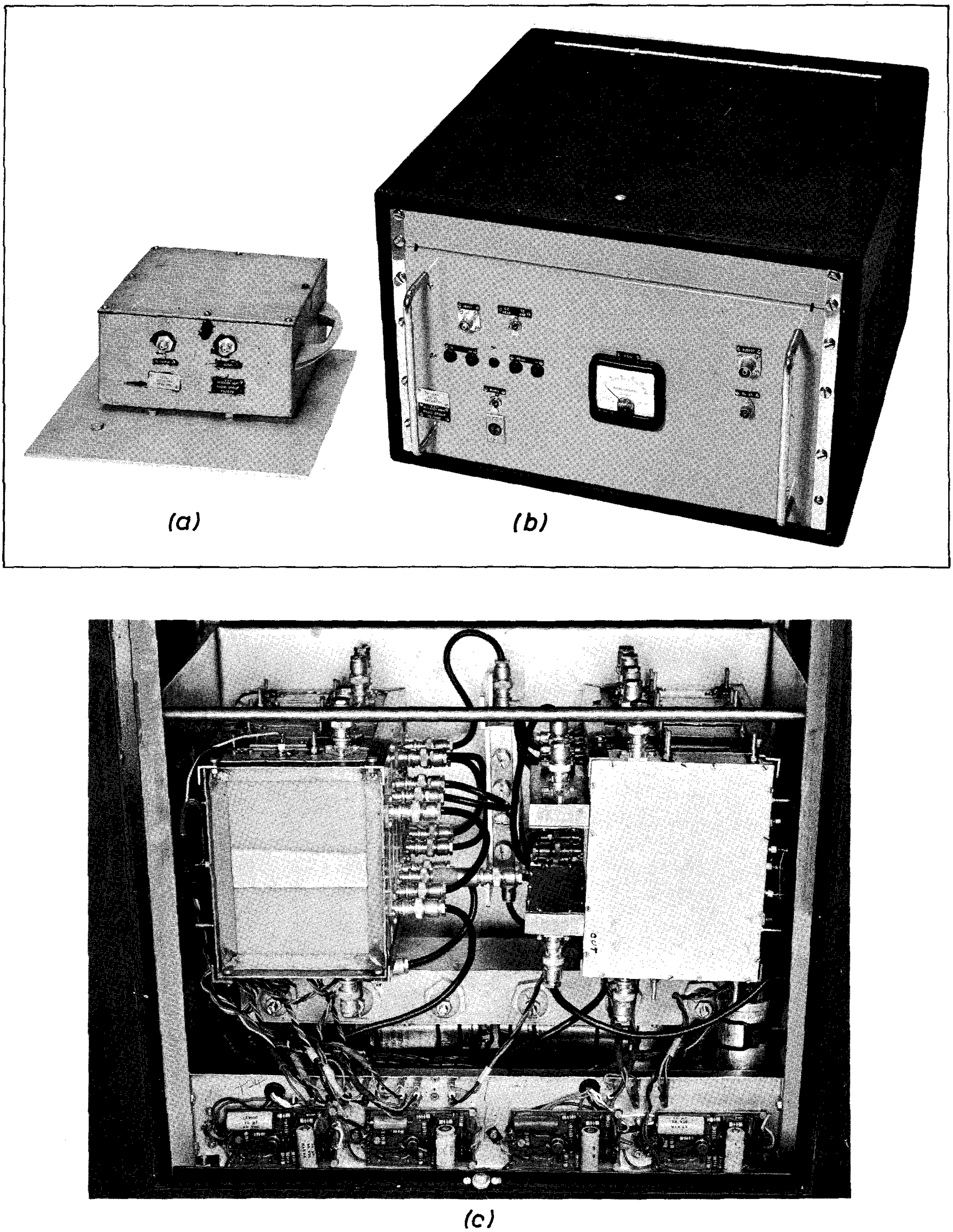

Fig. 1 - Photograph of the complete equipment

(*a*) Head Amplifier
(*b*) Main Unit
(*c*) Interior of main unit

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SUMMARY

This report describes equipment which has been developed to appraise active deflector transmissions for filling in pockets of low field strength within the main service area of u.h.f. transmitters. The equipment is portable and can be readily aligned on any channel within Bands IV and V. Details of the performance are given and other uses of the basic principle are discussed.

1. INTRODUCTION

One of the problems associated with the provision of a u.h.f. service is to find sufficient channels for the relay stations which are required to fill in pockets of low field strength within the main service area. A proposed method of economizing in channels is to receive, amplify and retransmit on the same frequency but with different polarization. Obviously the opportunities for using such a technique are limited and careful investigation will be required into ghosting effects at each locality in order to adjust the radiated power to minimize the number of affected viewers.

An alternative method of operation is to use the re-transmission of a main station to fill in a hole in a relay station service area. In this case the restrictions are not so severe.

An active deflector can also ease the problem of pick-up by a conventional relay station of the transmission from its parent main station if the deflector is sited in a favourable position for relaying the signal from the main station to the site of the relay station. In some cases justification and siting of the active deflector could be partly or wholly on the grounds of the saving of a s.h.f. link that would otherwise be required.

With the first of these systems, i.e. within a main service area where nearby viewers might use either the main station or the active deflector, a constant-gain amplifier with power limiting is preferable, whilst for the other two systems a constant output power is more suitable. During site tests it is usual to run with constant output power. Since a site-test transmitter may be required to operate on any u.h.f. channel between 470 and 854 MHz it must be capable of being re-aligned relatively easily.

2. GENERAL DESCRIPTION

The method adopted is to use a number of relatively wideband u.h.f. amplifiers together with two or three band-pass filters to define the required channel for amplification. For general reliability and ease of operation transistor amplifiers are used throughout for output powers of up to 1·5W peak combined sound and vision. If higher powers are required the transistor power amplifier stages may be replaced by a travelling-wave tube (t.w.t.) amplifier giving up to 50 W peak output.

With conventional valve or transistor amplifiers the rapid change of input and output impedance with frequency and the effect of internal feedback prevent the cascading of amplifying stages without appreciable interaction. To overcome this problem quadrature-fed amplifiers[1,2,3] are used; these consist of two identical amplifiers for which the input signals are derived from two terminals of a 3 dB directional coupler fed by the main input, and for which the outputs are combined in a second coupler. This system gives a good input and output match over a very wide frequency band and amplifiers can be operated in cascade without difficulty.

A photograph of the complete transistor equipment is given in Fig. 1 and Fig. 2 is a block diagram. The first two amplifiers together with a comb-line filter[4] are mounted adjacent to the receiving aerial. This avoids degrading the signal-to-noise ratio by the feeder loss to the main amplifier. Simple filters permit power to be fed to the head amplifiers via the feeder cable.

The first stage of the head amplifier and of the main amplifier uses low-noise transistors while transistors of higher gain are used for the following stages. In the main amplifier, one or two stages of

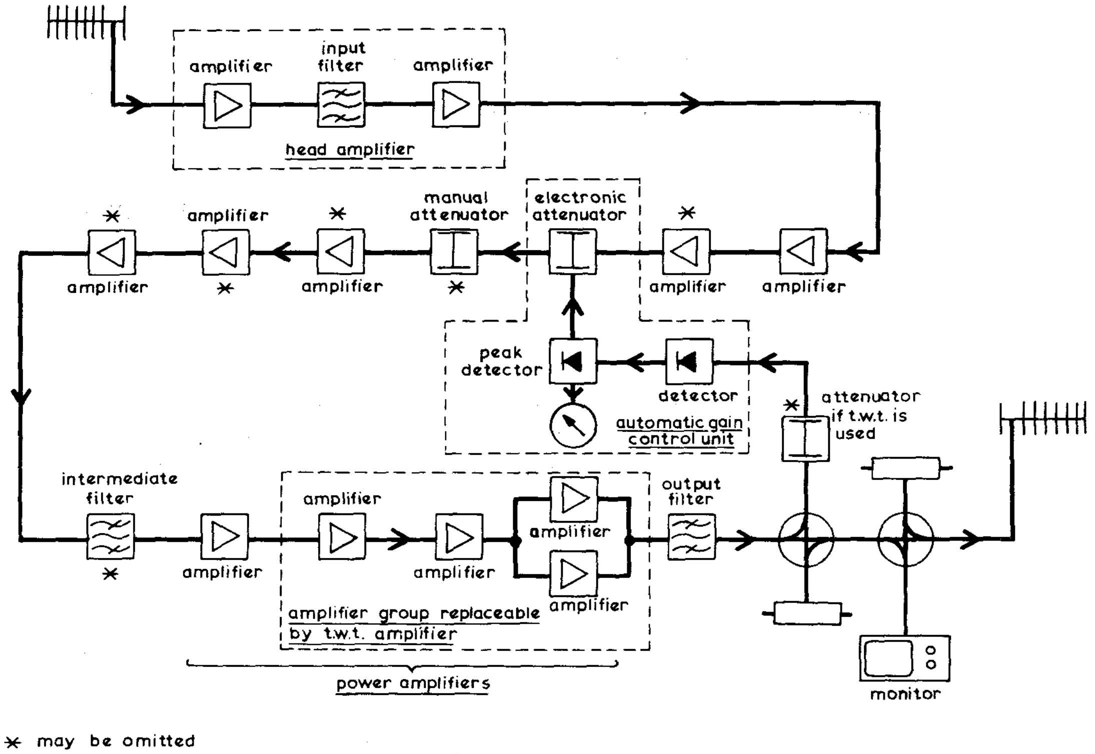

Fig. 2 - Block diagram

amplification precede an automatic gain control (a.g.c.) unit and this is followed by two or three amplifiers. If the overall gain is to exceed 65 dB a band-pass filter is inserted at this point to limit the amplification of noise at frequencies well below the required pass-band but still within the pass-band of individual amplifiers. Four higher-power amplifiers then follow to give a peak output power of the order of 1·5 W. The output of the final amplifier is filtered by a band-limiting comb-line filter whose main purpose is to limit intermodulation products which lie just outside the pass-band. Directional couplers between this filter and the output socket supply a monitor output and the peak detector which drives the a.g.c. unit.

It should be noted that, with the high overall amplification used, the transmitting and receiving aerials must be designed to have a very good isolation between them, typically more than 100 dB. The feeders must also be well screened and positioned for minimum coupling. Typical aerial gains used are from 12 to 15 dB on each aerial. Hitherto, site tests have been carried out with multiple Yagi aerials but these, being narrow-band, have to be adjusted for each channel. A photograph of an aerial is shown in Fig. 3.

3. BASIC AMPLIFIER

Fig. 4 is the circuit diagram of a basic amplifier while Fig. 5 is a photograph of a typical unit.

All the amplifiers have the same form of construction. An input 3 dB directional coupler of the transmission line type[5] splits the power into two equal-amplitude signals in phase quadrature which are then amplified by two identical transistor stages. The two outputs are recombined by another 3 dB directional coupler. Transistors with grounded emitters are used for most stages but some of the high-gain low-power amplifiers employ a grounded-base configuration.

In the highest-power stage two basic amplifiers are further combined by couplers, as described in Section 4, in order to obtain the necessary power output. All stages operate as Class A amplifiers to minimize distortion.

The 3 dB bandwidths of the individual amplifiers vary from more than 200 MHz for the low-noise stages to about 20 MHz for the highest-power amplifier. At low power, gains of up to 12 dB are achieved while the gain of the power amplifiers falls with increasing power to a minimum of 5 dB.

3.1. Input Circuits

The 3 dB directional couplers used to feed the transistors ideally have the property that their two outputs are equal in amplitude over a wide frequency range but are in phase quadrature at all frequencies. With identical loads any reflected signals will recombine in such a manner as to appear in the termination but not at the input. This means that for all frequencies at which the amplifiers are identical and the coupler is ideal the input will be perfectly matched.

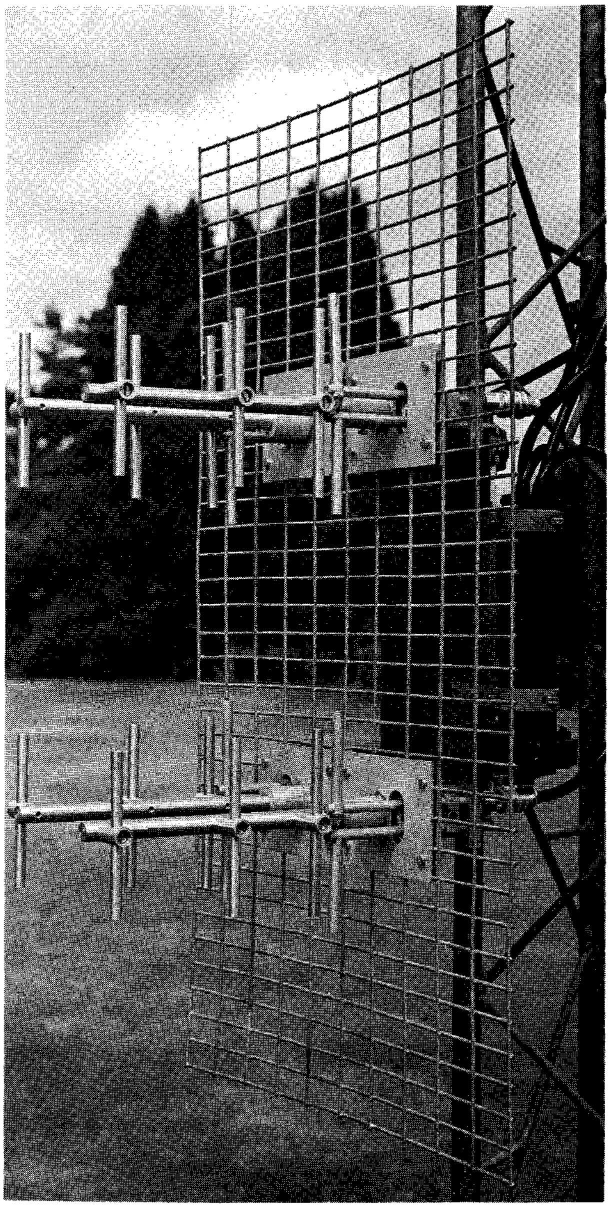

Fig. 3 - Photograph of a multiple Yagi aerial

In practice the reflected power at the input can be made very small by simultaneously adjusting the transistor input matching for maximum gain and good balance as indicated by minimum power into the termination. The matching section consists of two variable capacitors at each end of a transmission line one quarter-wavelength long at mid-band. This system has sufficient range of adjustment to cover the whole of the band 470 to 854MHz. The directional couplers and matching lines are constructed in strip-line using polystyrene as the main dielectric.

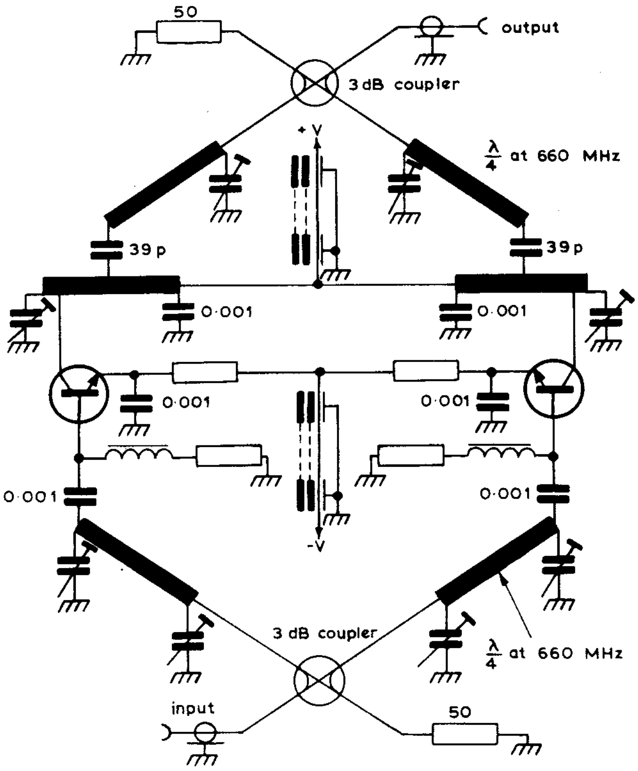

Fig. 4 - Circuit diagram of basic amplifier

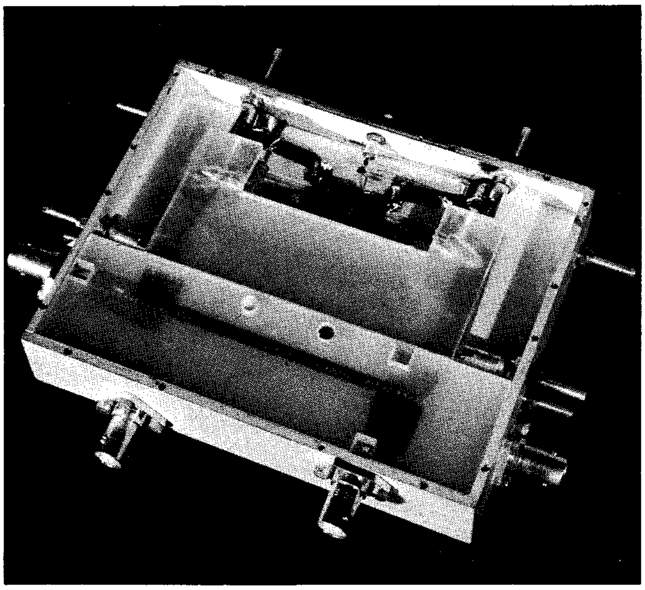

Fig. 5 - Photograph of basic amplifier

3.2. Output Circuits

The outputs of the amplifiers are matched and combined using a second 3 dB coupler. The collector loads, however, consist of tuned circuits rather than the simple capacitors as used for the input. In the low-power stages, the output lines are connected to taps on the inductive lines which form part of the tuned circuits.

4. THE POWER AMPLIFIER

One of the problems of power transistors at u.h.f. is that the input admittance increases with the power rating and, when combined with the internal lead inductance, gives rise to an unacceptably small bandwidth. In order to reduce these effects as far as possible and obtain the necessary output power it was decided to use two power amplifiers for the final stage. These two amplifiers are fed and combined by additional 3 dB couplers so as to avoid any power sharing and tuning problems between the four individual stages. Direct paralleling of transistors is not satisfactory in high-power stages as it can lead to thermal runaway in class A amplifiers.

In both this stage and the driver stage the working currents are adjusted to give maximum output power rather than maximum gain.

5. THE AUTOMATIC GAIN CONTROL UNIT

A completely satisfactory way to apply a.g.c. directly to a transistor amplifier has not been found, the main limitations being power handling capability and balance between the two transistors in one unit. In the system adopted, a circuit diagram of which is shown in Fig. 6, a 3 dB directional coupler is again used. This coupler is operated in the reflecting mode. Maximum attenuation occurs when the two lower arms are matched so that no power reaches the fourth arm which is the output terminal. This condition is achieved by adjusting the quarter-wave matching sections for maximum attenuation with the diodes (D5 and D6) heavily conducting. If now the currents in the diodes are reduced, power is reflected at the diodes and re-enters the coupler with a phase relationship such that the power emerges from the fourth arm of the coupler. In this way the attenuation may be reduced to a minimum of 1 dB while the maximum attenuation is over 30 dB.

The signal for operating the a.g.c. unit is obtained from the output of a directional coupler of about 30 dB coupling factor at the aerial-feeder terminal (see Fig. 2). This output is passed, via an attenuator if necessary, to a voltage-doubling detector D1 and D2. The video output, which is somewhat modified by the presence of the sound carrier, then feeds a peak detector consisting of an integrated-circuit operational amplifier with diodes D3 and D4 in the feedback path. This gives a rapid rise time but a long decay time. The output of the peak detector supplies a 'long-tailed' pair of amplifiers TR1 and TR2, one of which drives the a.g.c. diodes through an emitter follower TR3 and the other a front panel meter to indicate signal level. An adjustable d.c. bias to the operational amplifier allows the operating level of the a.g.c.

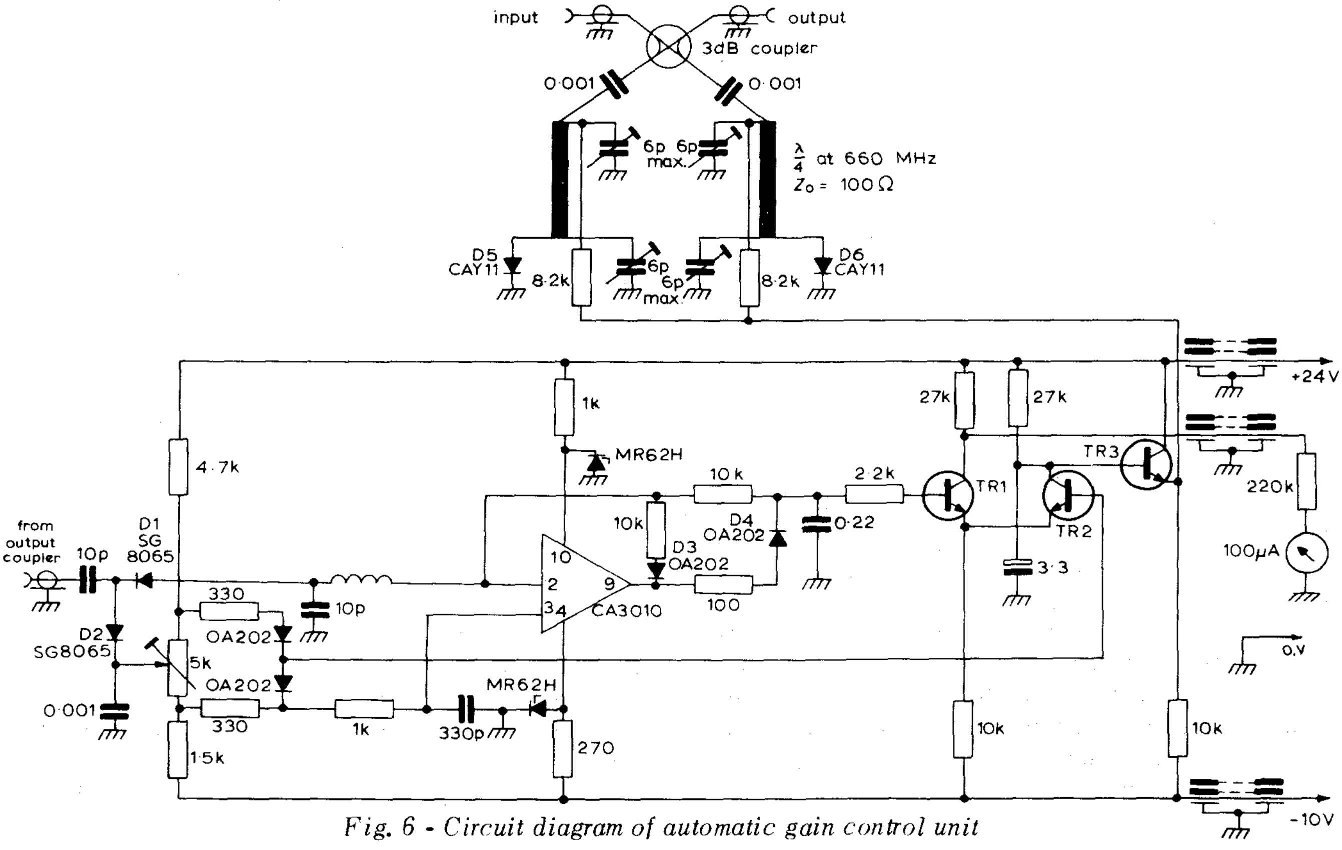

Fig. 6 - Circuit diagram of automatic gain control unit

unit and hence the output power to be set to the required value. A manual attenuator following the a.g.c. unit is pre-set so that the input level variations are as far as possible within the control range of the unit.

The manual attenuator, as shown in the circuit diagram of Fig. 7, consists of a pair of 3 dB couplers joined back-to-back so that the signal normally travels straight through. A two-gang variable capacitor has one section connected to each of the two junctions between the couplers. By varying this capacitor the amount of power reflected into the resistive termination of the first coupler can be varied, thus changing the attenuation. An attenuation range of 16 dB is obtainable. Larger gain changes can be obtained by removing amplifiers.

With the amplifier a.g.c. system adjusted for a constant power output, as described above, a change in u.h.f. input signal level of 30 dB, sufficient to carry the a.g.c. unit over its full range, gives less than 0·25 dB change on the transmitter output at any pre-set power level up to 1·5 W (or 50 W with the t.w.t. amplifier).

If it is necessary to operate the active deflector at constant gain, the output power is first set with a large input signal by adjusting the loop gain of the a.g.c. system for an output level above which distortion might occur. The manual attenuator is then adjusted to give the required overall gain for a small input signal. Under these conditions the a.g.c. will only operate if the input level becomes excessive.

6. FILTERS

The filter in the head amplifier (see Fig. 2) is a four-element comb-line filter.* Separate units are provided for 470 to 600 MHz and 600 to 854 MHz bands. Variable capacitors are used for tuning the individual resonators and adjusting the input and output couplings. The filters are designed to have a Tchebycheff response uniform to within ± 0·01 dB; in practice the response is substantially uniform over the pass-band of 12 MHz.

The main purpose of the input filter is to remove any signals outside the required channel which may be picked up by the aerial with sufficient strength to overload later stages of the unit.

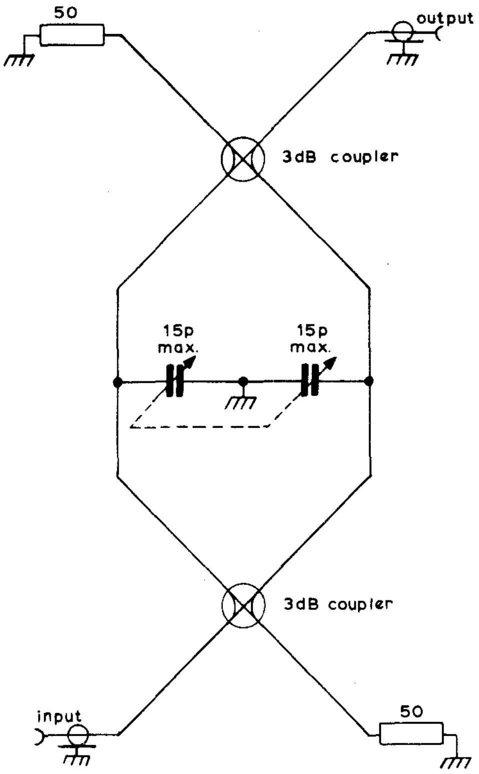

Fig. 7 - Circuit diagram of manual attenuator

The intermediate filter, when used, is of the same type as the input filter. It is inserted at the centre of the amplifier chain to limit the amplification of noise, which might otherwise lead to overloading at frequencies well outside the required pass-band.

The output filter is also of comb-line construction but is designed for low loss and has a narrower pass-band of 9 MHz overall. This is obtained by using six resonators and constructing the whole unit in a much larger and more substantial form. A photograph of the Band IV output filter is shown in Fig. 8.

7. HIGHER OUTPUT POWERS

When powers in excess of 1·5 W peak are required, the final three transistor amplifiers are replaced by a commercial travelling-wave tube amplifier. Powers of up to 50 W peak are then available. The same output filter can be used with the t.w.t. but an extra fixed attenuator will be required at the input to the a.g.c. unit.

8. POWER SUPPLIES

The transistor amplifiers use power supplies of +24 V, −10 V or −8·5 V d.c. These are provided from conventional transistor series stabilizers with

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* This filter is made to a design which was developed in BBC Designs Department, the basis being given in Reference 4.

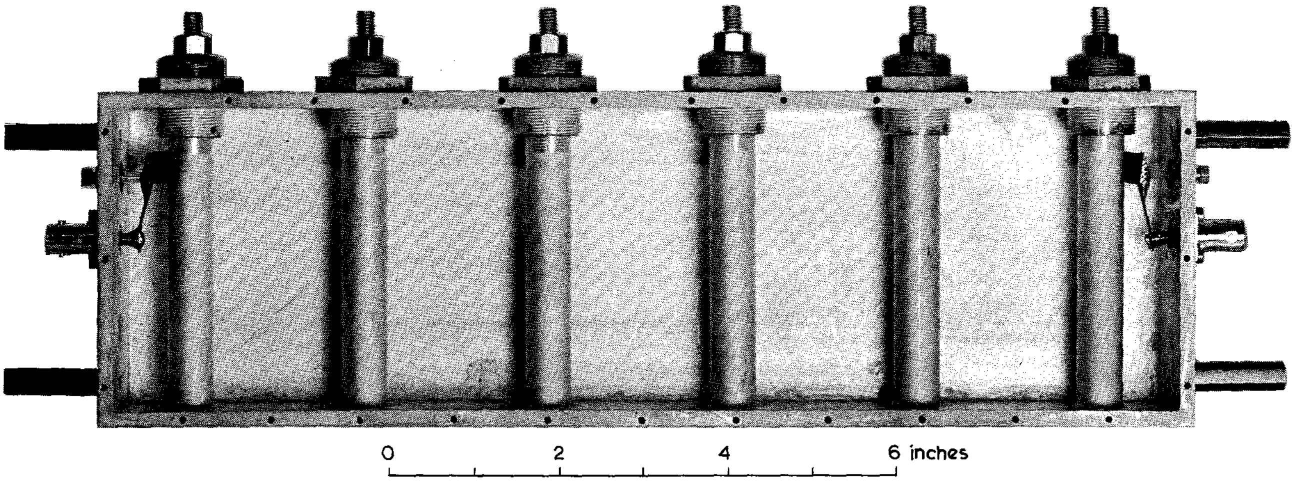

Fig. 8 - Photograph of Band IV output filter

full overload protection. For convenience the driver and output stages use separate stabilizers.

9. OVERALL PERFORMANCE

Within the pass-band (8MHz) the amplitude response is uniform to within ± 0·25dB and the group delay variation is less than ± 10ns. The overall delay is 370ns when the three filters are used. A minimum of amplifier delay is advantageous in permitting some relaxation in the otherwise very severe aerial isolation requirements as any small echo due to direct feedback is less visible with small delays.

The noise factor of the amplifying system is about 7dB on any channel in the 470 to 854MHz band.

Overall gains of up to 90dB can be obtained in the site-test equipment although, in practice, it would seldom be possible for an active deflector station ever to employ a gain in excess of 80dB owing to the presence of reflections from aircraft or other objects in the locality which may give rise to momentary ghosts or even instability.

The output power at 810MHz with the transistor amplifiers is at least 1·5W peak combined vision and sound signals (about 0·75W peak vision); higher output powers are, however, obtainable at lower frequencies. At the rated power levels all third-order intermodulation products are at least 50dB below the combined output signal. The input and output v.s.w.r. is better than 1·2 over the band.

By careful layout of the feeders and employing an output feeder with a corrugated-metal outer conductor, the coupling between feeders could be made negligible compared with that between the aerials. It was found that the isolation between the aerials themselves could be made more than 105dB in a typical site-test installation with the two aerials on the same mast and spaced vertically by 10m.

10. FURTHER APPLICATIONS

The equipment described so far represents that developed purely for the purpose of testing possible sites for active deflector stations. It may be of interest, however, to consider the extent to which equipment based on the same design principles might be used in service equipment.

10.1. Four Channel Operation

In the future, active deflectors are likely to be required to amplify up to four television programmes at once. The amplifiers described have not the necessary bandwidth or power handling capability to deal with this number of channels. After the initial head amplifier, however, a four-channel splitting filter could be used, followed by four separate amplifier channels each with its own a.g.c. unit, and a similar four-channel filter for combining. In this way a satisfactory overall performance could be obtained. The splitting filter could consist of four filters similar to those used at present in the site-test equipment but with the inputs coupled to a common input line.

10.2. Operational Translators and Active Deflectors

In the equipment described all amplification is achieved at u.h.f. In contrast, u.h.f. relay (translator) stations at present in operation, with relatively high powers, employ a double frequency change and achieve most of their amplification at an intermediate frequency (i.f.) of about 40 MHz. When a number of low-power relays of both the frequency-translator and active-deflector type are required, it would probably be advantageous to use similar standard units in the equipment. One way of achieving this would be to construct an active deflector with a frequency change to an i.f., followed by i.f. amplification and a frequency change back to the original frequency. On the other hand one could equally well adopt a straight amplifier for an active deflector, and make a translator by employing a single frequency changer preceded and followed by u.h.f. amplifier units and filters appropriate to the input and output channels, using the same basic concept as that employed in the site-test active deflector. Which arrangement is most suitable depends on a number of economic and technical factors outside the scope of this report, and may well depend on the output power of the relay stations under consideration.

11. RELIABILITY

It should be noted that besides having the general reliability of semi-conductor devices the amplifier design is such that the failure of one side of one of the amplifier units will only result in a fall of gain of 6 dB, the other side continuing to function. Whilst this would give rise to higher intermodulation products in some stages the active deflector would continue to function until such time as repairs could be carried out.

12. CONCLUSIONS

A simple versatile amplifier system has been designed primarily for site-testing active-deflector stations. Certain features of this equipment could, however, be applied to operational equipment for u.h.f. stations.

13. REFERENCES

1. ENGELBRECHT, R.S. *and* KUROKAWA, K., 1964. A wide-band low noise L-band balanced transistor amplifier. *Proc. IEEE,* 1965, **53**, 3, pp. 237 - 247.
2. British Patent Specification 723151.
3. British Patent Specification 735927.
4. JONES, W.L. 1965. Design of tunable comb-line filters of near-constant bandwidth. *Electronic Letters* 1965, **1**, 6, pp 156 - 158.
5. MONTEATH, G.D. 1955. Coupled transmission lines as symmetrical directional couplers. *Proc. Instn. elec. Engrs.*, 1955, **102B**, 3, pp. 383 - 392.

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